Oakley Greenwood

19 February 2009

By email to

David.swift@esipc.sa.gov.au

Dear David,

RE: A FRESH LOOK AT REACTIVE REQUIREMENTS IN THE NEM

OVERVIEW

Management of voltage at different points in an electrical power system has a major effect on the quality and security of supply of electrical energy (active power) to individual customers and the operation of the overall power system. Careful control of production and withdrawal of reactive power at different points in a network is the primary means to manage voltage.[1]

Responsibility for providing a capability to produce and consume reactive power and to maintain voltages has evolved alongside arrangements for the production and transport of energy in the NEM. However, these arrangements have not been a priority and in parts are now ad hoc resulting in increased regulatory overheads and transaction costs and potentially barriers to entry for new entrant generators. An increased level of investment in low emission technologies at remote locations is exacerbating the adverse impacts of the current arrangements.

This paper introduces a whole of market framework for investment and dispatch of reactive within the National Electricity Market (NEM) in response to your request for us to consider a fresh approach to managing reactive. The framework is applicable to the investments and operating arrangements of and for customers, distribution and transmission network businesses and generators. The overall arrangements for voltage control and reactive management in the NEM are extensive and while the framework would recast key parts of the arrangements many of the features and practices of the current arrangements do not require change and would not change under the framework approach.

1 Industry literature often refers to *real* and *unreal* components of electrical currents reflecting the mathematical theory of *complex numbers* that is used to analyse alternating current power systems. In general the voltages and currents in an a.c. power system are not in phase – this means that although both rise and fall with the same frequency (going through 50 cycles per second in a 50Hz system) current does not rise and fall at the same time as voltage. Using complex numbers the current flow is represented by a component that is exactly in phase (the so called *real* component) and a component that is completely out of phase (the *unreal* or *imaginary* component). Flow of the real component of current is determined by the voltage and electrical *resistance* of equipment, and flow of the unreal component is determined by the voltage and electrical *reactance* of equipment. As a result *real* and *unreal* power flows are also known as *resistive power* and *reactive power* and also as *active* and *reactive power* respectively. The combination of resistance and reactance is a *complex number* and is termed *impedance*.

The framework focuses on obligations of networks to manage voltage rather than reactive per se on the basis that reactive power is a “tool” to manage voltage and is not a primary commodity in the same way that real power is. A key element of the framework is that it leads to a reference point accountability that is a basis for case by case negotiation by relevant industry participants for practical and efficient provision and operation of reactive plant that is best suited for each location.

The framework is conceptual at present. Further work is needed to stress test the basic concept and identify areas that may need amendment and further development.

FRAMEWORK OPTIONS

BACKGROUND

This section briefly reviews a number of the options considered for revised arrangements. The search for a different environment for reactive started with a view that the current arrangements have grown from a situation where reactive requirements were fairly well established and considered to represent good industry practice, but are now less suitable for a mature market with major changes occurring in technologies of generating plant locating in remote locations. Although there were arguments about whether generators should have mandated requirements to provide reactive, the technologies in use were such that there was only limited cost impost associated with mandated requirements and networks were well meshed and additional reactive was not a major concern. Similarly customer power factors were monitored, but again there was no strong concern about the historical arrangements. Where there was lack of clarity about responsibility for providing reactive or voltage control this was manageable and tolerated by existing and new entrants, albeit not necessarily happily.

In considering options for change it became apparent that incremental change would be difficult because the current arrangements were developed on an as needed basis and are not cohesive. The option of a dramatic change to use marginally priced pool market for reactive might solve some problems but is likely to introduce more questions than it answers. At the other extreme a fully commercial arrangement would also be problematic. The framework that is proposed aims to makes change where it is needed without imposing unnecessary costs or adding risks of failure. It is flexible in that once established, basic settings, such as the customer entitlement, can be altered and this will shift part of generator contribution from an obligation to a commercial basis in a controlled manner. It is compatible with current arrangements for network regulation and provides a high degree of flexibility for networks to manage how they meet performance standards in respect of the management of voltage.

The following briefly assesses the options considered:

Incremental change

Incremental change would refine existing arrangements to correct obvious problems and fill obvious gaps. This approach is not proposed as the current problems are symptomatic of the absence of an over-arching policy and it would be difficult to know how changes should be made that may resolve one difficulty but create another leading to sequential changes, still without a clear policy setting. For example, new wind generators in South Australia are required by their licence conditions to include a capability to manage power factor at their connection point and while this may be appropriate for new remotely connected machines it may be unnecessary for a larger unit in a more tightly meshed part of the network. It is not clear that this should be a uniform requirement. As a result incremental change may see new connections required to meet a series of different specifications aimed at achieving different ends at different locations. Incremental change is therefore little different to the current situation and may lead to more even more “balkanisation” of the requirements.

Spot market

Arrangements for marginal pricing of reactive capability in a spot or pool market have been described by many authors within industry literature and aim to provide efficient prices for future investment and dispatch. More work could be considered in this regard but there would be many problems and questions to be resolved. Apart from technical issues relating to dispatch and measurement, a pool market would be problematic because the technical characteristics of a power system mean that reactive is not easily transported over large distances and as a result it would be difficult to proceed unless a market for reactive was close to a nodal market. A nodal market would not align with the NEM energy market and involve currently regulated bodies in an as yet undefined way and would also mean there were only limited participants in the market in many locations.

For the present purposes, it is assumed that a spot market for reactive is not a practical option for the NEM.

Commercial contract framework

A commercial contract framework would see all reactive supplied voluntarily under contract. This option has not been pursued on the basis that it would involve potentially large transaction costs and it is not clear how it would interact with the regulated network environment. Contracting impediments may inadvertently force networks to self procure reactive rather than optimise use of reactive capability of generators, other networks and customers. It has not been pursued.

Roles and responsibility framework

A roles and responsibility framework is proposed. It envisages that the role of networks (at least in relation to reactive) be defined as “transport service providers” with clearly defined obligations in respect of the quality of service for voltage, along with matching entitlement of customers and obligation of generators.

Although the framework introduces a whole of market approach, many features of the proposed framework are present in the current design of the NEM and in practice will lead to only limited change. However, in critical areas, such as the interface between remote generators and networks and debate about whether generators should have any level of mandatory reactive capability the proposal provides clarity and greatly reduces uncertainty.

DESIGN OF ROLES AND RESPONSIBILITY FRAMEWORK

This section describes the proposed framework.

For convenience the framework is described in terms of its four traditional structural parts: Customer, Distribution Network, Transmission Network and Generation. The framework assigns roles and responsibilities along with entitlements and obligations to the different parts and includes a mechanism to ensure efficient implementation.

Together these will establish reference point accountability for reactive for each party. The reference point will only rarely be the optimum arrangement as it is based on the structural division of the industry rather than technical and economic factors. All parties are expected to negotiate actual provision of voltage control capability from that reference point. Commercial and regulatory incentives should be included in the design to facilitate and encourage efficient negotiation outcomes.

The following summarises the roles, entitlements and obligations and identifies how commercial arrangements are required to optimise the final implementation.

ROLES

1. Customers and generators are market participants

2. Transmission and Distribution networks are transport agents from generators to customers - they are not market participants.

ENTITLEMENTS AND OBLIGATIONS

3. A minimum power factor entitlement will be set for customers (in principle it could be unity)

4. Regulated network businesses are required to provide the transport service within quality and performance standards

5. In principle, Generators are accountable for the supply of reactive entitlement (along with energy) needs of customers at no charge. Generators are not accountable for supply of any reactive needed by networks to deliver their transport service – but may agree to do so.

COMMERCIAL AND OPERATIONAL FLEXIBILITY

6. The framework recognises that the technical characteristics of networks may (and often will) lead to networks producing and consuming reactive in order to provide transport service

7. Customers, Transmission Networks, Distribution Networks and Generators may enter into commercial arrangements with each other to provide/consumer reactive in excess of their respective entitlements and obligations

8. Regulatory and commercial incentives should be designed to ensure commercial and operational arrangements optimise provision and consumption of reactive.

CONSTRUCTING THE FRAMEWORK

This section explains the derivation of the framework starting from the basic premise that the role of generators is to be accountable for supply of customer needs and networks to transport those requirements. Figure 1 shows the hypothetical situation of reactive production from generators entering the transmission network and an equivalent amount passing to distribution network and on to customers.

Figure 1 Generators supply customer needs, networks provide a transport service

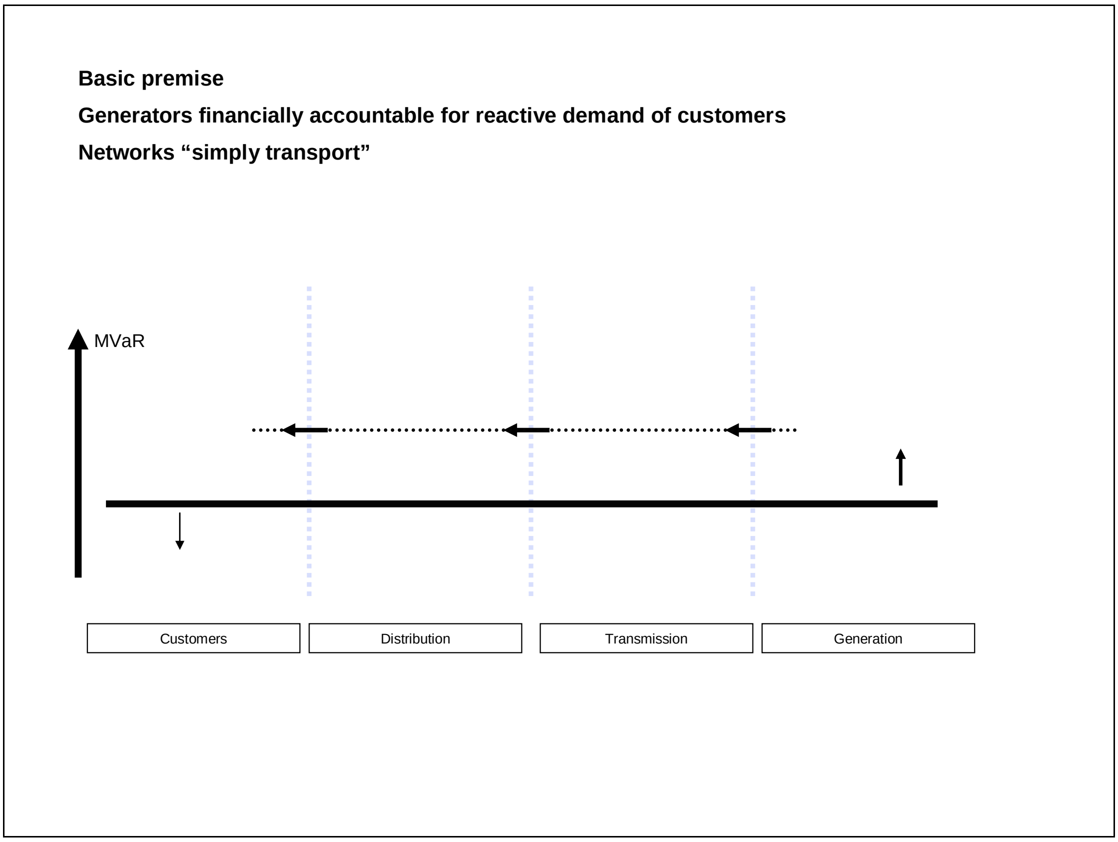
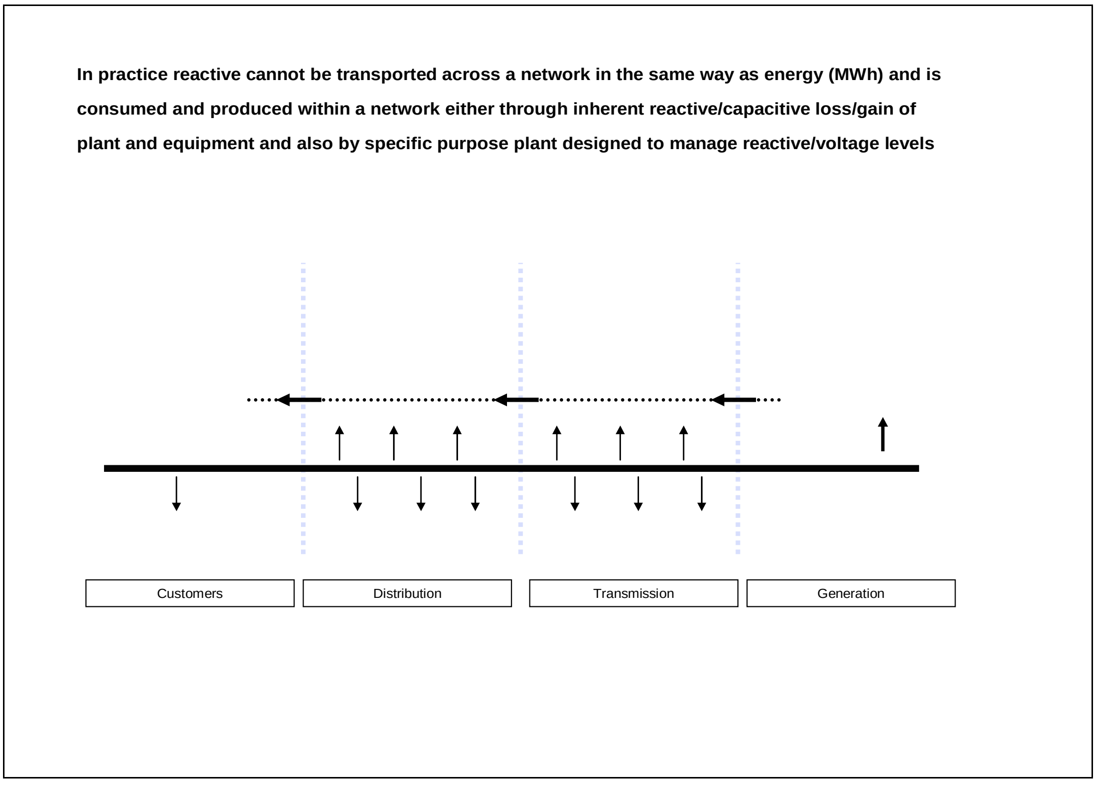


Figure 2 recognises that reactive cannot be transported as freely as energy and networks may be both consumers and suppliers of reactive.[2] Network businesses also employ equipment that can inject or absorb controllable amounts of reactive at different points on the network. Some of the controlled facilities can be fast acting plant (e.g. static VAR compensators) while other are switched in and out of service by controlled switching and give slower adjustments to changing circumstances.

Figure 2 Networks consume and create reactive



Network performance obligations

For the purposes of this framework the basic performance requirements of networks can be described as:

- Voltages at all points on a network must remain within safe limits for plant and equipment and within specified ranges at any point of connection to another participant, for example +/- 95% of nominal.[3] Importantly, the limits must be observed for steady state and contingency conditions and networks must therefore take whatever action is needed to ensure these limits are met within possible excursions agreed or advised by NEMMCO.

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2 Networks consume reactive in plant and equipment, for example in transformers and high voltage lines. High voltage lines also produce reactive (through an inherent capacitive effect of the lines) that reduces the net reactive requirement, and in very long lines this may result in the lines being net suppliers of reactive.

3 Arbitrary tolerance for illustrative purposes

- The networks should continue to function, that is to provide the transport service (within performance standards), following any defined single event including an internal fault that removes one of its own lines or major items of plant from service or an external failure due to a single credible event outside the network. Credible events outside the network will include generator outages in the case of transmission networks and transmission network failures for distribution networks.

These are in effect a simplified description of current performance obligations.

As a result network businesses will often need to install reactive plant above what would be needed on the own behalf but will be necessary to meet the full requirements of a transport service. Figure 3 through Figure 6 illustratively builds up the requirements for reactive plant on a network to meet the standards, with Figure 6 showing the reference point obligation for each network. The diagrams do not distinguish the location or nature of the reactive plant although it is recognised that it is likely to require a mix of static and dynamic plant across the network (the opportunity to optimise provision of plant in practice is noted in the subsequent sections).

Figure 3 Reactive requirements to maintain steady state voltages

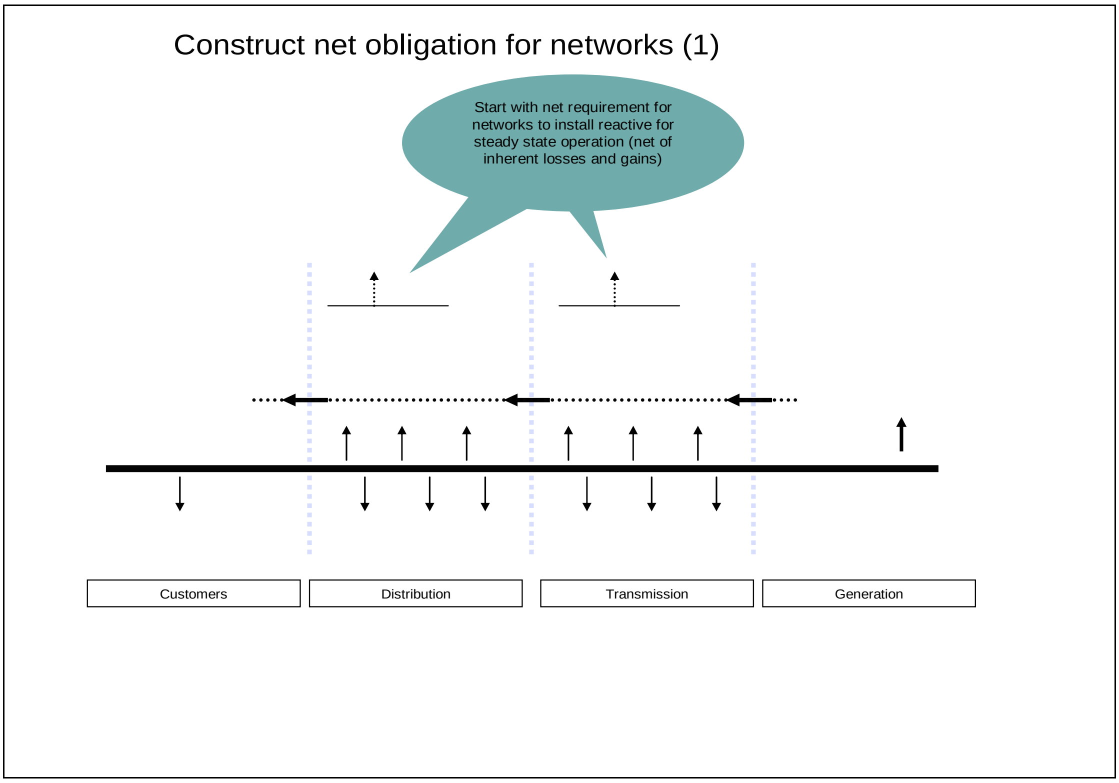


Figure 4 Adding the reactive requirements for internal network failures

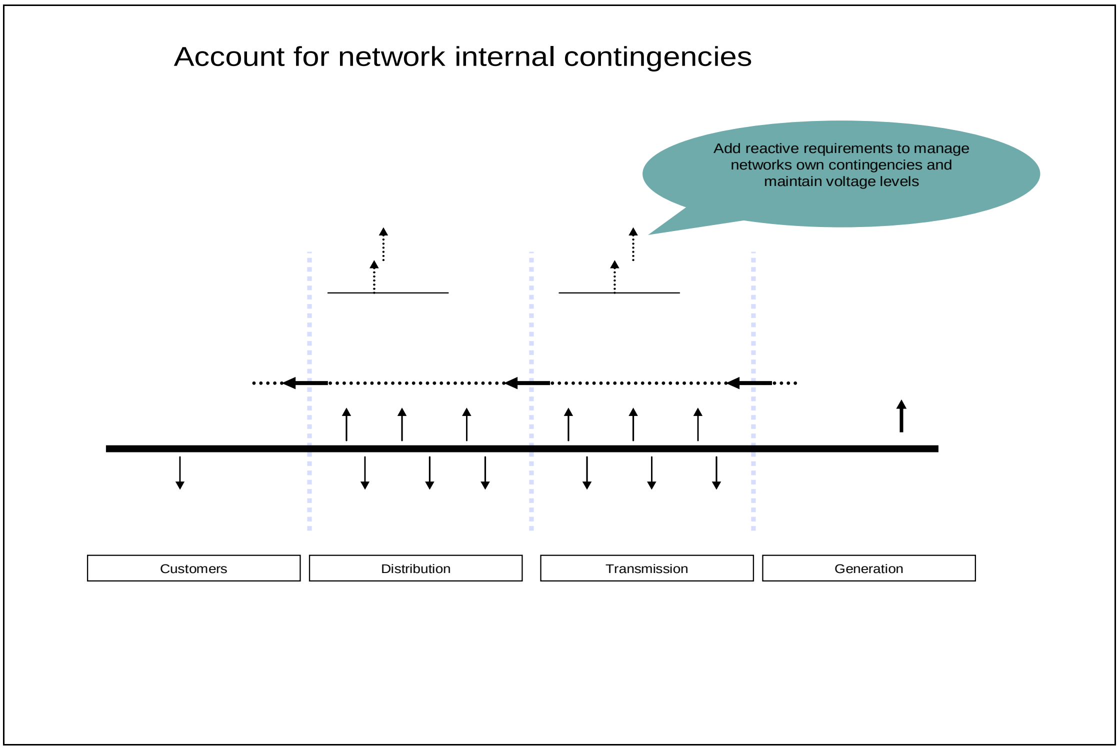


Figure 5 Adding network requirements to cater for external failures (steady state and dynamic effects)

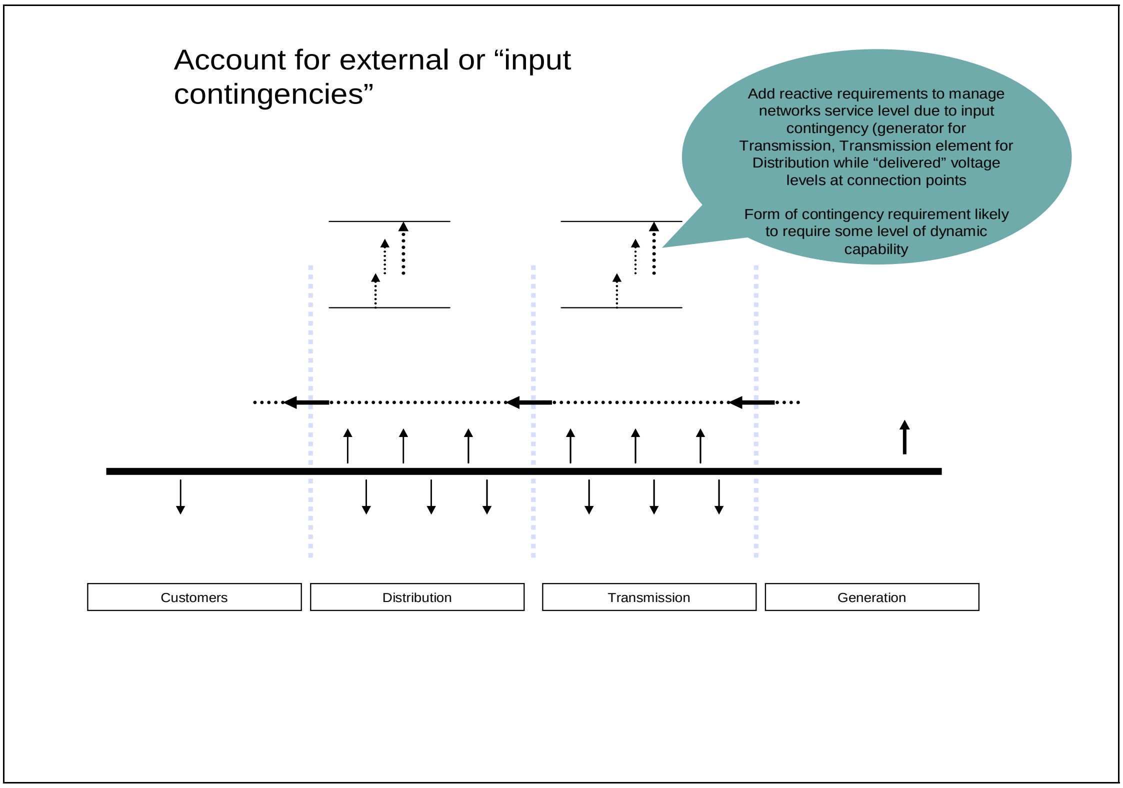
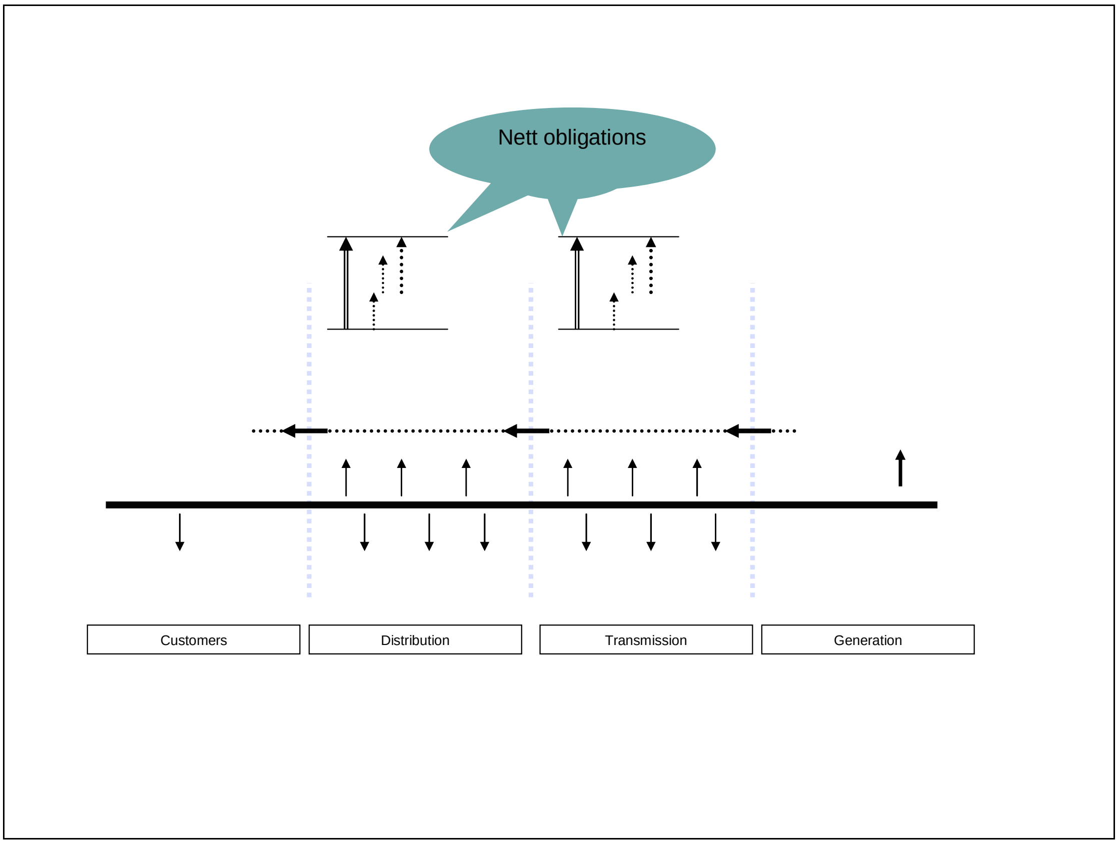


Figure 6 Reference point reactive obligations for reactive plant to be supplied by networks



Optimising provision between sectors

The reference point obligations will be based on accountability for the entities under the current structure of the industry and will only rarely be the optimum economic or technical mix of reactive sources across the overall industry. The optimum mix will vary depending on the circumstances including the location of different generators and technologies and the configuration of the network. The framework is premised on regulatory and commercial incentives encouraging networks, generators and customers to coordinate planning and operational procedures with the aim of optimising the practical sources.

The current arrangements in the NEM have a similar aim and the framework proposed here may not change the final physical arrangements cases where there has been no impediment to optimum design. In other cases, where accountability for voltage control and reactive is contentious the framework will have a larger effect, for example in the connection of new generation in remote areas, and in all cases it offers the opportunity to clarify the boundaries of accountability to reduce barriers to entry and transaction costs.

Figure 7 and Figure 8 illustrate just two areas where the industry entities would be expected to negotiate for different arrangements than that in the reference point. For example, generators would have a common accountability under the framework but the arrangement with local network businesses may mean that a generator in one location may provide significant reactive input to a local network to support voltages, but in another location provide very little as network reactive plant is more than sufficient. Negotiations at the time of forming a connection agreement and later agreements would provide for negotiated variations from the reference point. Importantly, there will be no expectation that the final provision of reactive capability aligns with the reference accountability under the framework.

Figure 7 Optimising provision of reactive from the reference point: Customer-DNSP negotiation

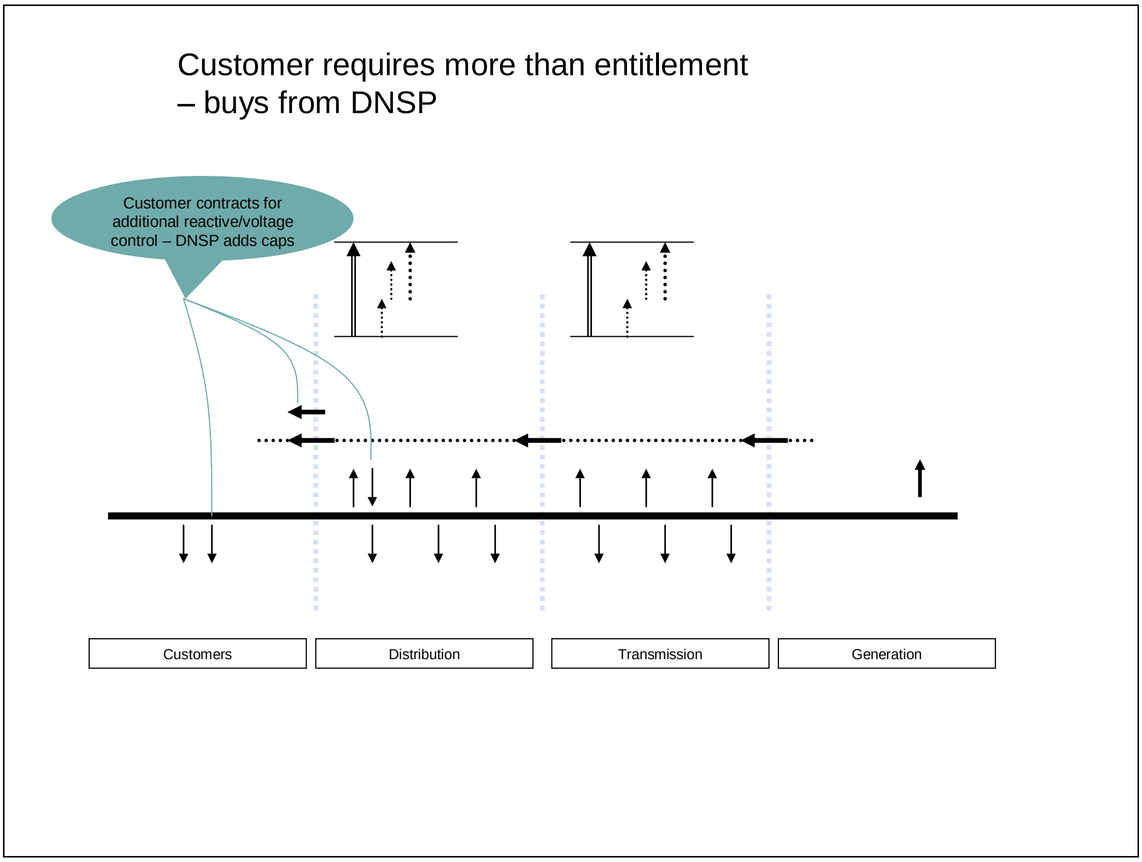
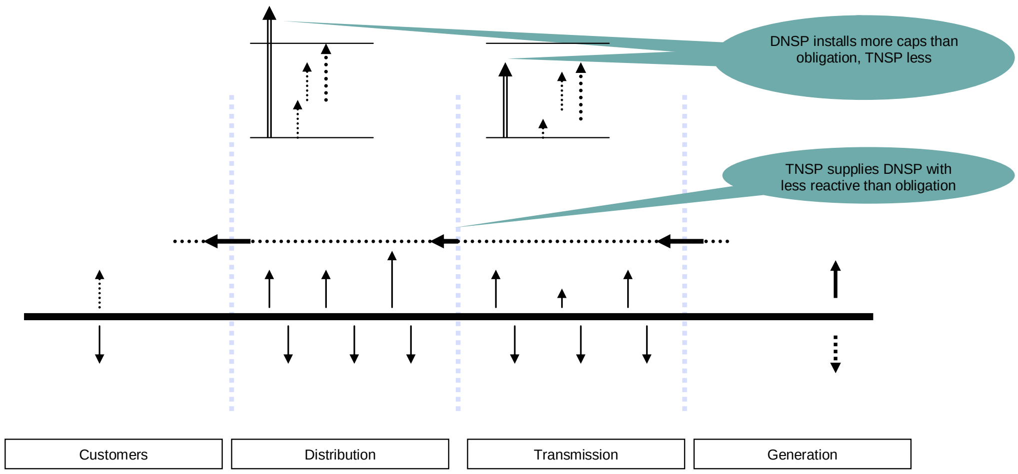


Figure 8 Optimising provision of reactive from the reference point: DNSP - TNSP coordination

TNSP and DNSP coordinate reactive investments – DNSP installs reactive in excess of obligation:
Receives financial contribution from TNSP



Devil in the detail and areas for further work

The concept of a reference point obligation for generators does implies a mandatory capability, and also implies that they will need to recover any costs of maintaining that capability in their energy charges. This is the status quo and while it is a matter that can be debated if desired, it should also be noted that it is derived from a design principle that generators are accountable for meeting the needs of customers, not networks. Applying this principle, customer entitlement can be varied within the framework and this would be matched by a corresponding change in generator obligation. For synchronous plant a mandatory capability obligation will not involve significant costs (assuming the requirement is set in a way that has little impact on energy production) but it may have a more material impact on asynchronous plant e.g. wind generators. This will mean networks and wind generators are more likely to negotiate a position where the network will physically install reactive on the network as a service to the generator in place of reactive contribution from a wind plant. On the other hand the performance service standard will place responsibility for managing voltage at a connection point with the network business, and if a network would prefer a wind generator to manage that voltage this would be a service provided by the generator.   Both of these positions will be affected by whether the network facilities needed are classified as part of a prescribed service and it is likely that there will need to be more clarity about this classification (regardless of whether the framework is adopted).

So far this description has focussed on the gross capability of reference point requirements. Further work is needed to consider if and how the reference point should account for broader range of matters including whether:

- customer reference point entitlements should include limitations on rate of change for reactive demand;
- generator obligations should include dynamic response elements – this may be a natural outcome of the detailed specification of generator reference point obligation in any event;
- network business service requirements should be limited to transport of energy as if it were a "prescribed service" under the current rules and if additional reactive is needed within a network to facilitate connection of a generator if this should be at the expense of the new entrant – tentatively the answer to this question would be *yes*, and this would avoid networks incurring costs in excess of "optimum" and to retain the current policy setting in this regard;
- arrangements that have been introduced and that require generators to control voltage at a connection point or regulate output to a specified power factor should be part of the reference point obligation or be a negotiated service. Discussion in the preceding paragraph assumes that voltage control at all connection points is a network responsibility, although a network may contract for a generator to manage voltage operationally on its behalf. This approach recognises that a generator can only be accountable for voltage when its operation is the sole factor affecting voltage, such as for a remotely connected generator. Once they are a number of parties involved or for connection points more closely meshed in the network a single generator will have only limited capability in this regard;
- (any) reactive to support spot market trading should be an obligation of TNSPs or TNSPs on behalf of NEMMCO or participants. This question is pertinent to NEMMCO's current review of network support services. The framework lends itself to TNSPs having responsibility for system or market based reactive support arrangements but would also allow for TNSPs to act as agents for NEMMCO if NEMMCO were to have (or retain) obligations in this regard. The proposed framework would provide a clear reference point for either approach; and
- how a transition from current arrangements should be handled – especially where parties have incurred costs that may now not be within their reference point requirements but have no commercial mechanism for redress and similarly if connections have been agreed to that fall below a new reference point requirement .